Beta Particles

- Beta decay results in the emission of an electron from the nucleus (positive or negative electron).
- They are light charged particles, are ionising and typically stopped by a millimetre of aluminium.
- B- decay the atomic number increases by 1 with the mass number constant & occurs in neutron rich nuclides.
  - A neutron is transformed into a proton + electron, with the electron emitted from the nucleus.
- B+ decay- the atomic number decreases by one and the mass number remains constant & occurs in neutron poor nuclides.
  - A proton is transformed into a neutron and a positive electron (an anti-electron positron) and the positron is emitted from the nucleus.
- The electron charge is denoted by e. As they have kinetic energy, they cause ionisation, having collisions and lose energy along their tracks.
- Examples: Beta particles:
  - Do contribute to patient absorbed dose- TRUE
  - Before coming to rest may travel in tissue for several millimetres – TRUE
  - Increase atomic number by one- TRUE
  - Change mass number in the nucleus- FALSE
  - Are emitted from the nucleus- TRUE
  - Are light-charged particles- TRUE
  - Are ionising- TRUE
  - B- decay occurs in neutron poor nuclides- FALSE
  - B+ decay occurs in neutron rich nuclides- FALSE
  - Have a charge of e- TRUE

Diagnostic reference levels

- A diagnostic reference level is a dose level, or amount of radioactivity used in a diagnostic procedure for a typical examination.
- It is not a dose limit.
- Each hospital sets its own DRL for a given examination and piece of equipment on which the examination is carried out. These DRLs should be compared with the national or European reference dose levels where these are available.
- DRLs can be assessed using entrance surface dose (ESD), kV and mAs, dose area product (DAP) or screening time.
- Different DRLs are set for different age ranges in paediatrics.
- DRLs should not be exceeded under standard conditions.
- Example- Concerning DRLs:
    - Are always measured in mSv- FALSE
    - Are nationally set- FALSE
    - Represent dose limits- FALSE
    - Are different for different ages of patient- TRUE
    - Are set for each piece of equipment- TRUE

Electron Capture

- Electron capture occurs in neutron poor radionuclides.
- In the nucleus the captured electron combines with a proton to form a neutron.
- The vacancy in the electron shell is filled by an outer orbital electron and the difference in energy between the orbits results in the emission of characteristic X-rays.
- The atomic number is decreased by one and the atomic mass number remains constant.
- Examples: Electron capture:
    - Occurs in neutron poor radionuclides- TRUE
    - Results in the emission of characteristic X-rays- TRUE
    - The atomic number remains the same- FALSE
    - The atomic mass number remains the same- TRUE
    - ^{123}I decays wholly by electron capture- TRUE

Isotopes

- Isotopes of an element are nuclides that have the same number of protons → identical atomic number and same chemical and metabolic properities.
- They have a different number of neutrons, a different mass number and there density and different physical properties.
- Examples- The isotopes of an element have:
  - Identical atomic numbers- TRUE
  - Identical atomic mass numbers- FALSE
  - Identical physical properties- FALSE
  - Identical chemical properties- TRUE
  - The same density- FALSE

Radioactivity

- Unstable nuclides, which have a neutron excess or deficit are radioactive and decay through a decay series until they become stable by emitting α, β or γ radiation.
- The activity of a radionuclide is the number of decays per second. The unit of activity is the Becquerel (Bq).
- The daughter product is not always radioactive (may be a stable nuclide at the end of the decay series).
- Examples- Radioactivity:
  - A radionuclide is an atom with an unstable nucleus- TRUE
  - The activity of a radionuclide is the number of decays per hour- FALSE
  - Unit of activity is the becquerel- TRUE
  - Radioactivity is a stochastic process- TRUE
  - The daughter product is always radioactive- FALSE

Kilovoltage across an X-ray tube

- E (photon energy) = h (Planck's constant) x f (frequency)
- The half value layer (HVL) is a measure of the penetrating power and the effective energy of the beam. The HVL and effective energy of an X-ray beam increases as the applied kV is increased.
- The heel effect is independent of the KeV and results in a relative decrease in X-ray intensity on the anode side of the beam.
- Examples- An increase in kilovoltage across an x-ray tube is associated with:
  - A shortening of the average wavelength of the X-ray spectrum- TRUE
  - A relative increase in emitted x-ray intensity- TRUE
  - An increase in penetration of the beam- TRUE
  - A decrease in the half value layer of the beam- FALSE
  - An increase in average frequency of the x-ray spectrum- TRUE

Photoelectric effect

- The photoelectric effect is the interaction of a photon and a bound electron and occurs approximately 10-30% of the time for a typical diagnostic spectrum in soft tissue.
- The electron is then ejected from the atom, leaving the atom ionised.
- Interaction occurs with the K-shell electron about 80% of the time and the L-shell electron about 20% of the time.
- The photoelectric interaction coefficient τ is proportional to pZ^3/E^3, where p is the physical density; Z is the atomic number and E is the photon energy.
- The photon energy predominates for contrast media, lead and the materials used in films and screens because of their higher atomic number than tissue.
- Therefore as the photon energy increases the photoelectric interaction occurs less frequently. It does result in the emission of characteristic X-rays from the atom but these are low energy in low Z materials and are absorbed locally.
- Examples- The photoelectric effect:
    - Occurs about 70-80% of the time- FALSE
    - Is the interaction of a photon and a bound electron- TRUE
    - Occurs more frequently as the photon energy increases- FALSE
    - Interacts with the L-shell normally- FALSE
    - Is a pure absorption process in biological materials- TRUE
    - Is an interaction between incident photon and loosely bound electron- FALSE
    - Causes the irradiated atom to be ionised- TRUE
    - Shows a general increase with increased photon energy of the x-ray beam- FALSE
    - Is an important mode of attenuation in diagnostic radiology- TRUE
    - Is independent of atomic number- FALSE

Compton Interactions

- In the Compton process a photon interacts with a free electron which recoils taking away some of the energy of the photon as kinetic energy.
- The photon is scattered in a new direction, with reduced energy.
- Scatter of photons can be in all directions. Greater the angle of scatter of the photon, greater is the energy and range of the recoil electron and greater the loss of energy of the incident photon.
- It is the predominant process for air, water & soft tissues at photon energies above approximately 30 keV.
- At 30 keV in soft tissues 50% of attenuation will be due to the Compton effect and 50% due to photoelectric interaction.
- At 50 keV in bone 50% of attenuation will be due to the Compton effect and 50% due to photoelectric effect.
- The probability that the Compton process will occur is proportional to physical density and electron density. It is independent of the atomic number of the material as the number of electrons per unit mass is approxiamately constant for most materials (where Z/A is approx. 0.5), with the exception of hydrogen (where Z/A is 1).
- σ is proportional to p/E and is independent of Z, where σ is the probability that the Compton process will occur. Examples- Regarding Compton interactions:
    - The scattered photon carries all the energy- FALSE
    - All scatter is in a forward direction- FALSE
    - They are responsible for 50% of interactions at 30 keV in soft tissue- TRUE
    - The probability of interaction per mm length is proportional to the tissue density- TRUE
    - The probability of interaction is proportional to the electron density- TRUE
    - Is the collision of a photon with tightly bound K-shell electron- FALSE
    - Results in increased energy loss with increased angle of scatter of the photon- TRUE
    - Is unaffected by the electron density of the scattering medium- FALSE
    - Is an insignificant process in image formation in diagnostic radiology- FALSE
    - Becomes less significant for imaging at greater energies- FALSE

Rotating anode X-ray tube

- An anode disk, 4-10cm or more diameter, usually made of tungsten-rhenium alloy → which has better thermal characteristics than pure tungsten and does not roughen as quickly.
- A thin molybdenum stem
- A blackened copper rotor, this increases radiation heat.
- Bearings, lubricated with a soft metal such as silver → enables the rotor to rotate around the axle.
- A stationary anode tube is not used with a high kV because of the build up of heat in the system. However, some low tube potential techniques may still require rotating anode technology, such as in mammography
- Output of the tube is proportional to mA and kV2.
- The efficiency of X-ray production is 1% (99% of electron interactions produce heat.
- Examples- in a rotating anode X-ray tube:
    - The anode is composed of a disc of pure tungsten for general radiography- FALSE
    - The rotor has a blackened surface to increase radiation heat loss- TRUE
    - An induction motor with a stator coil is used- TRUE
    - The rotor bearings are lubricated with thin mineral oil- FALSE
    - The molybdenum anode stem is designed to allow maximum heat conduction- FALSE
- Regarding a x-ray tube:
    - A low tube potential always suffices with a stationary anode- FALSE
    - A decrease in filament current tends to reduce the tube output- TRUE
    - A decrease in tube potential reduces the output of the tube- TRUE
    - A rotating anode x-ray tube for general use is not made of a tungsten-rhenium alloy- FALSE
    - Heat production in the tube is in the order of 98%- TRUE

Beam Quality

- The quality (intensity plotted as a function of photon energy) of the beam from an X-ray tube depends on:
  - Peak tube potential (kVp) since higher kVp produces a beam of higher average energy.
  - Rectification of the tube voltage, since this determines the kV variation with time.
  - Filtration, since filter is used to harden the beam (remove a greater proportion of lower energy photons).
- The tube current (mA) does not alter the quality.
- Examples- The quality of the beam is changed by increasing
    - Focus film distance- FALSE
    - Tube kilovoltage (kV)- TRUE
    - Exposure time- FALSE
    - Tube current (mA) with fixed Kv- FALSE
    - Tube filtration- TRUE

Scatter

- Scatter reaching the film may be reduced by:
    - Air gap, Use of a grid, Use of a cone by reducing the field size, Compression of patient or Lower kV
- Reducing the X-ray field size reduces the volume of scattering tissue and so decreases scatter.
- An air gap technique results in a large reduction in the intensity of the scattered radiation reaching the film/screen, this is typically a 30cm gap.
- For diagnostic X-ray beams the scatter distribution from Compton interactions is very approximately uniform in space (i.e. Is not heavily forward peaked)
- The measured scattered dose distribution from a patient shows a higher dose on the entrance side due to absorption in the patient of forward scattered radiation.
- Example- the amount of scatter reaching the film in diagnostic X-ray imaging can be reduced by using:
    - An air gap- TRUE
    - A grid- TRUE
    - Beam collimation in the X-ray assembly to reduce field size- TRUE
    - Increased X-ray beam filtration- FALSE
    - An increased tube potential between cathode and anode- FALSE
- Regarding scattered radiation:
    - The larger the field size, the less scattered radiation will be produced- FALSE
    - The air gap technique increases the amount of scattered radiation reaching the image receptor- FALSE
    - The amount of scattered radiation reaching the image receptor decreases as tube potential increases- FALSE
    - Forward scatter predominates at over 30 kVp- FALSE
    - The ratio of primary to scattered radiation may be as low as 0.1 in diagnostics- TRUE

Mammography

- Maximum energy in the X-ray spectrum is determined by the peak tube potential (kVp) across the X-ray tube.
- Low energies (18-20 keV) are required in order to distinguish the soft tissues by photoelectric interaction.
- Target material used is molybdenum- producing characteristic radiation of 17.9 keV and 19.5 keV.
- A K-edge beam filter of molybdenum is used to reduce all other energy X-rays in the spectrum as the filter is relatively transparent to its own characteristic (k-edge) radiation.
- Typical glandular breast dose from a single film is less than 2mGy.
- A focus to film distance of approximately 60cm is used.
- Compression moves overlying tissues laterally, reduces thickness of irradiated tissue and so decreases scatter and improves contrast.
- Film latitude refers to the range in optical densities that can be visualised. With mammography the atomic number doesn't vary much, so a greater film screen γ is preferable as this gives greater radiographic contrast.
- Contraindications to compression are intolerance and the presence of an open skin wound.
- Examples- Concerning mammography:
    - The maximum (peak) energy in the x-ray spectrum is determined by the characteristic radiation of molybdenum- FALSE
    - A k-edge filter is used- TRUE
    - The ideal radiation is 30 keV- FALSE
    - Typical mean glandular breast dose from a single film is 10mGy- FALSE
    - A focus to film distance of 100cm is used- FALSE
  - With compression:
    - A smaller volume of breast tissue is irradiated- TRUE
    - Less scatter results- TRUE
    - Fewer structures are overlying one another- TRUE
    - A film of narrow latitude is needed- TRUE
    - Is always used unless it is not tolerated- FALSE

Ionising radiation

- Deterministic effects are due to radiation induced cell death. The cell population might recover.
- They do not occur below a threshold dose.
- The threshold dose varies for different pathological conditions.
- The severity of the effect increases with dose and above the threshold dose, deterministic effects will be demonstrated.
- The probability of effects occurring depends linearly on dose with stochastic effects.
- Examples are prodromal syndrome (0.5 Gy), erythema (2.0), hair loss (3.0), eye cataracts (2-5), temporary suppression of ovulation (1.5-5), temporary loss of sperm (0.3-2) and death (whole body dose- 5 (LD_{50})).
- Examples- Regarding deterministic effects of ionising radiation:
    - A threshold must be exceeded before an effect is observed- TRUE
    - Cataract induction is an example- TRUE
    - The probability of a deterministic radiation effect is inversely proportional to dose- FALSE
    - The severity of effect increases with radiation dose- TRUE
    - Genetic effects are somatic effects- FALSE
  - With deterministic effects the following are true:
    - There is a threshold above which there is no effect- FALSE
    - The threshold dose is constant for different pathological reactions- FALSE
    - The severity of effect is dose dependent- TRUE
    - If there is full recovery of the patient, then effects are non-additive- TRUE
    - The probability of effects occurring depends on dose- FALSE

Employer duties under ionising radiation regulations (IRR) (2017)

- A radiation protection advisor (RPA) is responsible for advising the employer on the application of IRR 2017
- They must be consulted over all new installations and on the designation of areas.
- A radiation protection supervisor (RPS) must be appointed in all areas where there are local rules, whether controlled or supervised areas.
- Classified workers are employees likely to receive an effective dose greater that 6mSv or greater than 3/10 of an employee equivalent dose limit, e.g. For lens of the eye or skin.
- In IRR (2017), the dose limit for employees 18 years or over is 20mSv. A controlled area is necessary where there is significant risk to spread of contamination , or where a person is likely to receive E >6 mSv or 3/10 of employee equivalent dose limit.
- Patient doses to be as low as reasonably practicable (ALARP). There is no set limit they must be below.
- Examples- Duties of an employer under IRR (2017):
    - To ensure a RPA advises the employer on the designation of controlled areas- TRUE
    - To consult a RPA over the design of a new installation- TRUE
    - To set down local rules for the use of ionising radiation at work- TRUE
    - To appoint a RPS where local rules are required- TRUE
    - To ensure all persons to be classified, have a medical examination- TRUE
  - Radiation legislation requires:
    - All persons working with radiation to have their personal doses monitored- FALSE
    - All radiation workers to receive a whole body dose of less than 20mSv per annum- TRUE
    - A controlled area to be defined only if the instantaneous dose rates exceed 7.5uSv per hour- FALSE
    - Patient doses to be below certain prescribed limits- FALSE
    - The employer to be responsible for ensuring that patient doses are ALARP- TRUE

Concerning IRR (2017)

- It is the responsibility of the employer under quality assurance to monitor and maintain the safety of equipment.
- A controlled area is one in which doses are likely to exceed 30% of a dose limit per annum.
- A supervised area is one in which doses are likely to exceed 10% of equivalent dose limit, or exceed a whole body effective dose of 1 mSv per year.
- These areas are defined in the local rules.
- Systems of work are procedures to keep dose as low as reasonably practical (ALARP) and <30% of dose limits.
- Effective dose limit is 1mSv to a member of public.
- The limit on equivalent dose for the skin is 500mSv averaged over any 1cm2 area regardless of the area exposed for employees, and 50mSv for a member of the public, 13 mSv during any consecutive 3 month period to the abdomen of a woman of reproductive capacity.
- The effective dose for employees is 20mSv per year, 50mSv in special circumstances where the employer demonstrates to the HSE that it cannot meet the 20mSv/calendar year limit.
- Examples- Concerning IRR (2017):
    - It is the responsibility of the employee to monitor and maintain the safety of equipment- FALSE
    - A controlled area is one in which doses are likely to exceed 30% of any dose limit for employees over 18 years of age- TRUE
    - Dose limits are irrelevant when defining a supervised area- FALSE
    - Controlled and supervised areas are defined in the systems of work- FALSE
    - Local rules allow non-classified persons to enter a controlled area- TRUE
  - States the following dose limits:
    - 5 mSv to the whole body of a member of the public- FALSE
    - 150mSv to the lens of a radiologist- TRUE
    - 50 mSv to the individual organs or tissues of a radiographer- FALSE
    - 10 MsV during an consecutive 3-month period to the abdomen of a woman of reproductive capacity- FALSE
    - 20 mSv per year averaged over 5 years, but no more than 50 mSv in a single year, to the whole body- TRUE

Statutory Responsibilities

- Dose must be kept as low as reasonably practical.
- Practitioners and operators shall have successfully completed training, including theoretical knowledge and practical experience.
- An ARSAC license is granted to an individual practitioner.
- All NHS hospitals are subject to IRR (2017), IRMER (2017) and EPR (2013).
- Examples- Regarding statutory responsibilities:
  - IRR (2017) are governed by the principle of as low as reasonably achievable- FALSE
  - IRMER (2017) lays down measures on the health protection of individuals against the dangers of ionising radiation in relation to medical exposure- TRUE
  - Radioisotopes can only be administered by someone who holds a license of adequate training- TRUE
  - An administration of radioactive substances advisory committee (ARSAC) licence is granted to the health authority or trust- FALSE
  - Crown immunity exempts all NHS hospitals in the UK from the regulations governing the storage of radioactive materials- FALSE

Personal Doses

- Workers who receive less than 30% can be classified. If they receive more, they must be classified.
- It is unusual for any X-ray department worker to be classified.
- Records must be kept for 50 years.
- Examples- Concerning personal doses:
    - Workers who receive less than 30% of a dose limit cannot be classified- FALSE
    - A nurse who works permanently in an X-ray department is usually classified- FALSE
    - The radiation dose records of a classified worker must be kept for 2 years- FALSE
    - Personal monitoring badges must be worn by all unclassified radiologists performing fluroscopy- FALSE
    - The as low as reasonably practicable (ALARP) principle applies to occupational dose as well as patient dose- TRUE

Radiation doses to patients and staff

- The current statutory dose limit for members of the public is 1 mSv per annum. In comparison the natural background radiation dose is around 2.2 mSv per annum in the south east of the UK.
- The effective dose from an AP pelvis radiograph is approximately 0.7 mSv.
- A member of staff must become a classified worker when their whole body dose is likely to exceed 6mSv per annum, or if they are likely to exceed 3/10 of any other equivalent dose limit.
- The lifetime risk of harm is approximately 1 in 20’000 per mSv (so, for 2 mSv the risk would be approximately 1 in 10’000)
- Examples- Regarding radiation to patients and staff:
    - Under IRR (2017) the effective dose limit for members of the public is 1 mSv per annum- TRUE.
    - A patient may receive approximately 4 mSv effective dose from an AP pelvis examinatIon- FALSE
    - Carers and Comforters may receive 5mSv over 5 years- TRUE
    - A member of staff may have to be classified if their effective dose looks likely to exceed 1mSv per year- FALSE
    - The fatal cancer risk for an effective dose is 2 mSv is approximately 1 in 500’000 weighted over a population aged 18-60- FALSE

Film γ

- The film characteristic curve is a plot of optical density versus log of exposure.
- Gamma can be defined as the average slope between two points on the characteristic curve, normally 0.25 and 2.0.
- Sometimes γ can be specified at one point on the curve to reflect the slope of the curve at a particular density.
- If γ >1 there will be an increase in radiographic contrast.
- An increase in grain size is associated with increased speed and a small increase in γ.
- A uniform grain size increases film γ, whereas a large range reduces film γ.
- Examples- Film γ:
    - Is a plot of film latitude versus log exposure- FALSE
    - Depends on emulsion crystal size- TRUE
    - Increases with time of developing- TRUE
    - Increases with temperature of developer- TRUE
    - Low γ film is used in mammography- FALSE

Radiographic contrast

- Radiographic contrast = film contrast x subject contrast.
- Radiographic contrast is the density difference between two defined areas in a radiographic image.
- Film contrast is a function of the film screen combination.
- It is affected by the characteristic curve, film density and processing, as well as by the use or not of screens.
- Use of screens can increase the γ when compared to a system without screens.
- Examples- Radiographic contrast can be increased by the following means:
    - Compression of the region under examination- TRUE
    - Increasing the tube kilovoltage- FALSE
    - Use of a secondary radiation grid- TRUE
    - Increasing the area irradiated- FALSE
    - Use of intensifying screens- TRUE

Subject Contrast

- Subject contrast is formed as a result of the range of the radiation intensities transmitted by the patient.
- It is altered by:
  - kVp, density, thickness, Z, scatter and the use of a contrast agent.
- Examples- Subject contrast is reduced by:
    - Film γ is reduced- FALSE
    - Development time is too short- FALSE
    - Film is over exposed- FALSE
    - kV is increased- TRUE
    - Size of beam is increased- TRUE

Radiation dose to patients and members of the public

- The effective dose for a PET 18F-FDG scan is 5mSv.
- The annual dose limit for members of the public is 1 mSv.
- Natural background radiation averages about 2.2 mSv.
- The average annual dose for diagnostic medical radiation is 0.37 mSv.
- The entrance surface dose of a chest radiograph is 0.3 mGy.
- Examples- Regarding radiation dose to patients and members of the public:
    - The effective dose for a positron emission tomography (PET) head scan with 18 F-FDG is 5 mSv- TRUE
    - The effective dose limit to the public is 1 mSv per annum- TRUE
    - The background radiation dose is approximately 6 uSv per day- TRUE
    - Medical exposures contribute approximately 0.3mSv on average per capita annuallu to the UK collective dose- TRUE
    - The entrance surface dose of a chest radiograph is 0.03 mGy- FALSE

Image intensifiers

- A Huttner line pair phantom (part of Leeds test object kit) may be used to measure limiting resolution from the monitor image.
- During fluroscopy the input dose rate is normally between 0.2 and 2 uGy^{-1} at the image intensifier input plane.
- The input phosphor consists of caesium iodide.
- The output phosphor is formed from zinc-cadmium-sulphide (silver doped).
- Brightness gain = flux gain x minification gain
- The smaller the field of view selected, the more magnified the image appears, so improving the limiting spatial resolution detected.
- Example- Regarding image intensifiers:
    - The limiting resolution can be measured with a line pair phantom- TRUE
    - The II input kerma rate at the image intensifier face is normally in the range of 0.2-1.0 $uGYS^{-1}$ during fluroscopy- TRUE
    - The output phosphor is made out of caesium iodide- FALSE
    - Brightness gain is sum of flux gain and minification gain- FALSE
    - Measured spatial resolution us usually poor on magnified fields of view- FALSE

Digital image intensifier and TV System

- The TV system limits spatial resolution due to:
  - The mosaic structure of the TV camera image plate
  - Line structure of the TV image which affects vertical resolution
  - Band width of the TV monitor electronics which affects horizontal resolution
- The resolution of a TV screen is 1 lp/mm (line pairs per mm). The resolution of a film/screen combination is 5-20 lp/mm.
- Film averaging can reduce quantum noise. Noise is random so averaging frames will reduce noise. As a result the signal noise ratio is improved by a factor equal to the square root of the number of frames averaged.
- Focus skin distances must not be less than 30cm and should preferably be greater than 45cm, especially on non-mobile X-ray systems.
- A dose area product (DAP) meter is mounted on the diaphragm housing, close to the tube focus and away from the patient to avoid radiation back scattered from the patient.
- Examples- Concerning digital image intensifier and TV systems:
  - The TV camera is the limiting factor on the system's spatial resolution- TRUE
  - Film screen resolution is poorer than image resolution in fluroscopy- FALSE
  - Frame averaging images can reduce the effects of quantum noise- TRUE
  - The focus skin distance should be preferably not less than 45cm on stationary imaging equipment- TRUE
  - Energy imparted to the patient cannot ne estimated with a dose area product meter positioned on the tube beam port- FALSE

Radiopharmaceuticals used for diagnostic imaging

- A pure γ emitter is ideal, i.e a radiopharmaceutical which decays by isometric transition, or electron capture → as producing extra particles only increases patient dose.
- A short half life will minimise the irradiation of the patient and stability in vivo enhances imaging.
- Radiopharmaceuticals with a high mass number, are more likely to decay by α and β- emission. Ideally the daughter product will be stable, leading to minimal further irradiation of the patient.
- Examples- Radiopharmaceuticals used for diagnostic imaging should ideally:
    - Emit photons with an energy greater than 300keV- FALSE
    - Have a physical half-life of more than 4 days- FALSE
    - Decay to a stable state- TRUE
    - Be a pure γ emitter- TRUE
    - Be stable in vivo- TRUE

Computed tomography (CT)

- In a 4th generation scanner, the detectors are stationary. Only the X-ray tube rotates.
- Whereas in 3rd generation scanners, both the detector, array and tube rotate.
- Spatial resolution deteriorates with increased slice width or pixel size.
- The tube anode/cathode axis, is perpendicular to the fan-beam plan, and parallel to the detector array.
- Increasing slice thickness will increase the partial volume effect.
- Examples- In CT:
  - Third generation scanners rotate detector array and tube- TRUE
  - Xenon gas can be used as a detector- TRUE
  - Slice width affects spatial resolution- TRUE
  - Tube anode/cathode axis is perpendicular to the detector array- FALSE
  - As slice thickness increases, the partial volume effect tends to decrease- FALSE

The nucleus of every atom

- Contains neutrons and protons, except hydrogen which only contains a proton.
- The valence electron is in the outer shell.
- Atomic number refers to the number of protons in the nucleus, the mass- the number of protons and neutrons.
- In a non-ionsed atom, the number of protons equals the number of orbital electrons.
- Examples- The nucleus of every atom contains:
    - A neutron- FALSE
    - A proton- TRUE
    - A positron- FALSE
    - A photon- FALSE
    - An electron- FALSE
- Examples- Concerning atomic structure:
    - The outer shell electrons are termed valence electrons- TRUE
    - The transition between L and K or M and K-shell gives rise to characteristic radiation- TRUE
    - The atomic number is equal to the number of neutrons- FALSE
    - The mass number is always equal to the number of protons- FALSE
    - The atomic number equals the number of electrons in a neutral non-ionised atom- TRUE

Radioactivity

- The law of radioactivity decay states that the activity of a radioactive sample decreases by equal fractions (%) in equal intervals of time.
- The rate of decay of a given sample (number of nuclei undergoing a radioactive transition per unit time) is proportional to the number of remaining nuclei present at that time.
- The effective half-life (teff) is a result of elimination from the body (biological half-life (tbio)) and physical decay half-life (tphys) of the nuclide. The effective is always shorter than either the physical or biological half-life.
- There may be several γ-rays emitted during a radioactive decay of a given radionuclide. These have a few specific energies, which form a line spectrum, that is characteristic of the nuclide which emits them.
- Temperature will not affect nuclear decay processes.
- Examples- Regarding radioactivity:
  - A fixed number of atoms decay per unit time- FALSE
  - Effective half-life is always shorter than biological or physical half-lives- TRUE
  - The energy is characteristic of the radionuclide- TRUE
  - Iodine-131 emits β particles- TRUE
  - Radioactive decay depends on temperature- FALSE

Spectrum obtained from an X-ray tube

- The peak tube potential gives the maximum energy that an electron can have to collide with the anode, and hence the maximum X-ray photon energy possible in the beam.
- The X-ray yield or efficiency of X-ray production increases with atomic number of the target anode.
- The characteristic lines in the spectrum are characteristic of the target material. Filtration tends to reduce intensity and also affect the spectral shape.
- The spectrum is independent of the distance from anode to cathode (the voltage difference is the same) and the tube current merely changes the number of photons, not the spectral shape.
- Examples- The spectrum obtained from an X-ray tube:
    - Has a maximum energy determined by the peak tube potential (KVp)- TRUE
    - Depends of the target material- TRUE
    - Varies with distance from the anode to cathode- FALSE
    - Is affected by filtration- TRUE
    - Varies with the tube- FALSE

Single phase vs three phase generators

- With a rectified or non-rectified single phase generator there is a different ditribution of X-ray energies at different times as the tube potential varies over the mains cycle from maximum to minimum.
- With three phase or constant potential kV waveforms the tube potential is close to the peak tube potential over the whole mains cycle so on average the voltage is greater and certainly closer to the set kVp than for a single phase generator.
- Hence for a single phase generator there is a larger proportion of lower energy photons compared to a constant phase generator for a maximum tube potential (kVp).
- The lower mean energy of the single phase spectrum means that the beam is less penetrating and a higher entrance surface dose (ESD) must be given to the patient in order to expose the image receptor to the required dose → overall a greater X-ray dose to the patient results.
- For given values of kVP and mA the three phase generator generates more X-ray photons and hence a greater tube output. This allows a shorter exposure time to attain the required receptor dose. One does not always require a three phase generator to use a high speed tube, in practice high speed tubes tend to have three phase generators however.
- Examples- In comparison to the single phase generator, a three phase generator:
    - Is more commonly found in older X-ray systems- FALSE
    - Provides greater output for the same radiographic factors- TRUE
    - Gives a reduced skin dose to the patient for the same exposure- TRUE
    - Allows a shorter exposure time- TRUE
    - Is always required for use with a high speed rotating anode tube- FALSE

Radiation output from an X-ray tube

- The output is proportional to Z (atomic number), kV^2, mA, and $1/d^2$ (where d = distance from target)
- The output increases with a constant potential compared to a single phase waveform. The output decreases with increasing filtration.
- Example- The radiation output (measured at the entrance surface of the patient) from an X-ray tube increases with:
    - Increasing kilovoltage- TRUE
    - Increasing tube current- TRUE
    - Increasing atomic number of the target- TRUE
    - The use of filters- FALSE
    - Increased distance to the patient- FALSE

X-rays in the X-ray tube

- X-rays are produce when fast moving electrons are suddenly stopped by impact on a metal target, penetrating into the target and lose their energy in two ways:
  - Interaction with the outer electrons of the atoms producing heat (99%)
  - Interaction with either the inner shells of the atoms, or the field of the nucleus (bremsstrahlung interaction) producing X-rays (1%)
- Examples- X-rays produced in an X-ray tube as a result of interactions between:
  - Moving protons and target electrons- FALSE
  - Moving protons and target protons- FALSE
  - Moving electrons and target nuclei- TRUE
  - Moving neutrons and target nuclei- FALSE
  - Moving electrons and inner shell target electrons- TRUE

Dose measurements

- Using a higher kV increases the tube output per mAs and makes the beam more penetrating- increasing the intensity and number of photons incident on the patient actually reaching the image receptor.
- As a result, a lower entrance skin dose is needed for the same exit dose (and hence receptor dose). Therefore, increasing the kV reduces the skin dose and the dose to the deeper tissues → this phenomenon is most pronounced for tissues near the surface and has little effect for doses near the exit site of the beam.
- Optical density is controlled by kV
- The object of filtration is to remove a large proportion of the lower energy photons before they reach the skin or deeper → reducing the overall intensity of the beam, meaning that the mAs may need to be increased- but the overall effect is to reduce entrance surface dose.
- Smaller field sizes save dose because they reduce the size of the irradiated anatomy and scatter. The percentage depth dose (100% being the entrance surface dose) tends to be greater with larger field sizes at a given depth.
- A larger focal spot has no effect on dose (for a given target angle)
- Examples- Dose measured or calculated at depth in the patient:
    - Increases when tube potential increases but optical density is kept constant- FALSE
    - Increases when tube potential increases but mAs product remains the same- FALSE
    - Increases when filtration decrease, all other factors being equal- TRUE
    - Is completely independent of entrance field size at the patient surface- FALSE
    - Is dependent on focal spot size, all other factors being equal – FALSE

Doses for staff

- Dose investigation levels are set within a department & are investigated if exceeded. This level would be set below the 3/10 of a maximum annual dose limit.
- A classified worker- an employee likely to receive greater than 6 mSv effective dose or greater than 3/10 of any other employee equivalent dose limit (e.g. Skin, extremities).
- Classified workers require a yearly medical by an appointed doctor to be certified fit.
- Workers do not have to stop radiation work but changes may be made to their working practices as a result of the local investigation into the dose received to ensure doses are being kept as low as reasonably practicable.
- The health and safety executive should be notified of the following: 1. dose exceeding dose limit, 2. medical exporsure much greater than intended, 3. loss or theft of source, 4. release or spillage leading to significant contamination.
- Examples- A whole body bimonthly dosimeter reading of 7mSv was recorded by a female member of staff in the radiology department. In accordance with IRR (2017), the following should happen:
    - An investigation should be carried out immediately- TRUE
    - The health and safety executive (HSE) should be notified- FALSE
    - She should immediately become a classified worker- TRUE
    - The member of staff should have a medical examination- FALSE
    - The member of staff should stop working with ionising radiation immediately- FALSE

Radiation Protection

- RPA normally works in the medical physics department. The radiation protection committee should have management representation.
- A referrer (GP) is not a practitioner or operator under the IRMER regulations.
- Radiographers are operators under IRMER regulations and normally would not be acting as a practitioner under IRMER in this context.
- Authorisation can be performed by the practitioner or by an operator acting under written guidelines.
- For stochastic effects, the probability of an effect occurring (not its severity) increases with dose. Whereas for deterministic effects, once a threshold is exceeded, the severity of the effect increases with dose.
- The equivalent dose (mSv) is the absorbed dose (mGy) multiplied by the radiation weighting factor for the radiation used. The dose equivalent is a previous definition of radiation dose by the ICRP and is not mentioned in the regulations.
- A classified worker is a member of staff who has been classified a radiation worker, requiring statutory health and radiation monitoring.
- Local rules specify the procedures needed to ensure compliance with the law. They cover safety organisation, descriptions of controlled areas and the systems of work for working in the controlled areas and for restricting access to them.
- Examples- Concerning radiation protection:
    - Radiation Protection Advisors normally reside in the X-ray department- FALSE
    - The radiation protection committee should have a representative of the hospital management in it- TRUE
    - A GP who requests a chest radiograph is clinically directing the examination- FALSE
    - A radiographer who performs a chest X-ray acts as a practitioner under the IRMER Regulations- FALSE
    - During pacemaker wire insertion, the radiographer authorises the exposure- TRUE
    - Stochastic effects are defined as biological effects whose incidence is proportional to the dose, provided a threshold is exceeded- FALSE
    - The dose equivalent is the same as the equivalent dose- FALSE
    - A classified worker is someone who has attended a “core of knowledge” course and is therefore trained in the use of ionising radiation- FALSE
    - Stochastic and genetic effects always occur when tissues are irradiated- FALSE
    - Local rules are to allow for circumstances where radiation exposure could occur- FALSE

ARSAC

- ARSAC licensing falls under the IRMER 2017 REGULATIONS
- Physical direction of an examination may be performed by other staff identified and instructed by the ARSAC license holder.
- The application is signed by the radiopharmacist, senior scientist responsible for the facilities and the RPA.
- An individual granted an ARSAC LICENSE has to renew it every 5 years. Research ARSAC licences may be for a shorter fixed period or number of patients.
- The ARSAC licence holder is ultimately responsible for the discharge of patients.
- The maximum dose to the patient is defined in the ARSAC certificate by the maximum activity of the radiopharmaceutical that can be administered.
- Examples- Regarding the Medicines (Administration of Radioactive Substances) Regulations:
    - Procedures can only be carried out by an ARSAC certificate holder- FALSE
    - The application for an ARSAC certificate has to be signed by a Radiation Protection Advisor- TRUE
    - An ARSAC certificate is usually valid for 10 years- FALSE
    - An ARSAC certificate holder is responsible for discharging patients from the Nuclear Medicine department- TRUE
    - The maximum dose to the patient is defined in the ARSAC certificate by the half-life of the radiopharmaceutical- FALSE

Annual Whole Body Doses

- Most health workers would probably receive less than 1mSv per annum.
- Doses to staff groups vary but a significant amount of fluoroscopy or interventional radiology could mean greater doses.
- In many cases cardiologists get greater doses than radiologists who in turn receive more than radiographers.
- IRMER (2017) requires diagnostic reference levels (DRLs) to be set for investigations.
- There are no dose limits for patients undergoing medical exposures under IRR (2017).
- IRR (2017) sets dose limits for workers and members of the public, of which patients in waiting rooms are included.
- Examples- Concerning annual whole body doses:
    - Most health workers receive less than 3mSv per year- TRUE
    - For radiographers are usually higher than for radiologists- FALSE
    - For radiologists are usually higher than for Cardiologists- FALSE
    - Limits are defined in IRR (2017) for patients while undergoing radiographic examination- FALSE
    - Patients in an X-ray department waiting area are regarded as members of the public- TRUE

Staff and patient dosimetry

- The dose area product (DAP) meter ionisation chamber is mounted on the light beam diaphragm, well away from the patient to avoid back scatter.
- The ESD for a lateral lumbar spine is approximately 10mGy, whilst for an AP abdomen it is approximately 4 mGy.
- The time of onset for a transient erythema is between 2 and 24h and 2Gy is the lower threshold dose.
- Examples- Regarding staff & patient dosimetry:
    - A dose area product (DAP) meter should be placed between the patient and the film- FALSE
    - The skin entry dose for a lateral lumber spine is usually more than that of a plain abdominal film- TRUE
    - Examinations of the limbs and joints make up over 10% of the collective dose from medical examinations- FALSE
    - The mean annual effective dose for medical workers is typically less than 0.2 mSv- TRUE
    - A single fraction of 2 Gy may cause a transient erythema which would be expected to be maximum at 24 hours- TRUE

Gadolinium oxysulphide screens

- Intensifying screens have the following advantages:
  - Patient dose redcution
  - Shorter exposure time, so reducing motion artefact
  - Improves image contrast
  - But reduce spatial resolution
- Screen speed can be increased by increasing:
  - Thickness of the phosphor layer
  - Crystal size
  - Conversion efficiency
  - Absorption efficiency
- Intensifying screens increase γ from about 2 to 3
- Examples- Gadolinium oxysulphide screens:
  - Increase unsharpness relative to calcium tungstate screens- FALSE
  - Are faster than non-screen film- TRUE
  - Display increased speed with increased crystal size- TRUE
  - Their speed increases with increased thickness- TRUE
  - Have relatively little effect on film/screen γ compared to non-screen film- FALSE

Unsharpness

- Sharpness or blurring is the ability of X-ray film/ film-screen combination to reproduce a distinct edge as a line.
- In the image receptor the thickness of the screen affects the diffusion of light out from where the X-ray photon is absorbed and hence the resolution.
- Resolution is also affected by crossover of light from front to rear emulsions and vice versa, grain size, beam parallax and screen film contact.
- Image sharpness is also affected by patient motion, geometry (penumbra, magnification and focal spot size).
- Blurring is reduced by:
  - Using a smaller focal spot
  - Decreasing the object-film distance
  - Or using a longer film focus distance which also reduces magnification and distortion
- Movement blurring may be reduced by immobilisation and by using short exposure time. However, this is not counted as geometrical unsharpness.
- Examples- Unsharpness:
    - Is decreased with the use of a screen- FALSE
    - Increases with increased kVp- FALSE
    - Decreases with increased film object distance- FALSE
    - Decreases with increased tube patient distance- TRUE
    - Is decreased with the use of fine grain films- TRUE
  - Geometrical unsharpness is decreased if the:
    - Effective focal spot is decreased in size- TRUE
    - Film-focus distance decreases- FALSE
    - Object to film distance increases- FALSE
    - Patient movement is captured on the image- FALSE
    - Exposure time is too short- FALSE

Brightness Gain

- Brightness gain = flux gain x minification gain
- Flux gain = acceleration of electrons by potential applied across image intensifier
- Minification gain = diameter input phosphor squared divided by diameter output phosphor squared.
- Examples- With image intensifiers, brightness gain:
  - Increases with increase in voltage across the intensifier- TRUE
  - Increases with decrease in the output phosphor size- TRUE
  - Is increased by the use of a calcium tungstate input phosphor- FALSE
  - Is increased by increasing the exposure to the input phosphor- FALSE
  - Is increased by the use of the horizontal position- FALSE

Zinc-cadmium-sulphide output phosphor

- The Zn-Cd-sulphide output screen converts the electron beam (not X-rays) back into green light.
- The camera pick up tube may have a lag of several hundred milliseconds thus causing image lag.
- However, in comparison the lag of the image intensifier tube is negligable being around only 1ms.
- Intensification factor = minifictation gain x flux gain (up to 15’000 for large image intensifiers)
- Examples- The zinc-cadmium –sulphide output phosphor in an image intensifier:
    - Absorbs only a small percentage of the X-rays- FALSE
    - Has a lot of afterglow- FALSE
    - Emits blue light- FALSE
    - The eye is sensitive to its emissions- TRUE
    - Has an intensification factor of FALSE

Quality control tests of X-ray equipment

- kV can be measured directly using a potential divider or indirectly with a penetrameter, with the actually kV being within +/- 5%.
- An ion chamber measure dose, not time.
- A spinning lead top on top of a film during an exposure can be used to measure exposure time. On modern equipment, this function has been added to the kV meter to produce a dual purpose device.
- Fluoroscopy with an image intensifier –TV achieves spatial resolution of 1lp/mm. Total filtration should be 2.5mm Al except for mammography and some dental units and this will generally be satisfied for a measured beam HVL of 2.8mm Al at 80 kVp.
- Film-screen contact can be checked by radiography of a perforated metal sheet placed on top of the cassette.
- Examples- In carrying out quality control tests of X-ray equipment:
    - kV can be measured with a film senitometer- FALSE
    - Timer accuracy is measured with an ion chamber- FALSE
    - A spatial resolution of 12 lp/mm would be acceptable for a fluoroscopic barium examination- TRUE
    - At 80 kV, a half value layer (HVL) of 2.8mm Al would indicate adequate filtration- TRUE
    - Film/screen contact is tested with a resolution grid inside the cassette- FALSE

Effective dose in radionuclide imaging

- In radionuclide imaging dose increases in proportion to:
    - The activity administered
    - The effective half-life of the radionuclide (1/effective = 1/biological + 1/physical half lives)
    - The energy of the radiation emitted
    - The emission yield (of percentage emission of γ-rays per disintegration)
  - This varies between different nuclides.
  - Examples- In radionuclide imaging, effective dose is:
    - 10 mSv for an 800 MBq cardiac muga scan on an adult patient- TRUE
    - Inversely proportional to the administered radioactivity- FALSE
    - Dependent on the γ-emission probability per disintegration- TRUE
    - Dependent on the biological half-life of the nuclide- TRUE
    - Independent of image acquisition time- TRUE

Spatial resolution in CT

- Spatial resolution is the ability to distinguish two objects. It is improved by:
    - Decreasing slice thickness
    - Increasing matrix size
    - Decreasing pixel size
    - Reducing the field of view
- Below a certain pixel size, spatial resolution if further limited by the size of the focal spot, collimators, number and size of detectors, and spacing between the detectors.
- Low contrast spatial resolution is limited by the noise in the image.
- Examples- Spatial resolution in CT depends on:
    - Slice thickness- TRUE
    - Slice spacing- FALSE
    - Pixel size- TRUE
    - Window level- FALSE
    - Matrix size- TRUE

Electromagnetic Radiation Spectrum

- X-rays have a shorter wavelength than visible light and hence a higher frequency.
- Electromagnetic radiation does not include particulate emission from radioactive decay.
- It is impossible to distinguish between two wave packets of electromagnetic radiation of the same energy as to whether they are from an x-ray or γ-ray.
- Electromagnetic radiation energy per photon (keV) = 1.24/wavelength (in nm).
- Auger electrons are not EMR.
- Examples- Regarding the electromagnetic radiation spectrum:
  - X-rays have a higher frequency than visible light- TRUE
  - A wavelength of 532nm corresponds to green light- TRUE
  - An x-ray and γ-ray photon of the same energy can be distinguised- FALSE
  - An electromagnetic quantum has energy inversely proportional to its wavelength- TRUE
  - EMR includes Auger electrons- FALSE

Diagnostic x-ray tube output

- Output is decreased by an increase in filtration as the lower energy X-rays are filtered out preferentially to higher energy ones, with the overall intensity at all photon energies is reduced.
- Output is proportional to kV2 and mA
- The anode material will affect the yield of X-rays produced.
- Output is unrelated to focal spot size (for the same target angle).
- Examples- The output from a diagnostic X-ray tube:
    - Can be increased by an increase in the filtration- FALSE
    - Is reduced by lowering the kVp- TRUE
    - Depends on the anode material- TRUE
    - Is proportional to the tube current- TRUE
    - Is inversely proportional to the focal spot size- FALSE

Intensity of the radiation from an x-ray tube at a given point in the primary beam

- Intensity is the total amount of energy per unit area passing through a cross section per unit time (aka energy fluence rate at that point).
- It is dependent on tube current and on the atomic number of the target material and is proportional to atomic number Z.
- The radiation intensity follows an exponential attenuation law when passing through a material: $I(x) = I(o) – e^{-ux}$ (x= thickness of tissue and o = the incident intensity.
- According to the inverse square law, the intensity of the radiation is inversely proportional to the square of the distance from a point source.
- Examples- The intensity of the radiation from an X-ray tube at a given point in the primary beam depends on the:
    - Tube current (mA)- TRUE
    - Atomic number of the target material- TRUE
    - Distance between the cathode and anode- FALSE
    - Thickness of the added filtration- TRUE
    - Distance to the target0 TRUE

Tube filtration

- The aim of filtration is to remove a large proportion of the lower energy photons before they reach the skin.
- This reduces the dose received by the patient while hardly affecting the radiation reaching the film, and so the resulting image.
- It is usually made of aluminium for general diagnostic tubes.
- National standards require that the total filtration is not less than 2.5mm Al for general X-ray tubes, 1.5mm for dental units operating below 70kVp and not less than 0.03mm molybdenum for mammography units.
- Examples- Added tube filtration:
    - Decreases the intensity of the X-ray beam- TRUE
    - Is usually made of copper for diagnostic purposes- FALSE
    - Increases the skin dose to the patient- FALSE
    - Changes the quality of the emergent X-ray beam- TRUE
    - Should give a total filtration equivalent to 2.5mm aluminium operating upto 150kVp

X-ray attenuation in materials

- Half value layer (HVL) is the thickness of the stated material that will reduce the intensity of a narrow beam of x-radiation to half its original value.
- HVL = 0.69/u, where u is the linear attenuation coefficient which measures the attenuating properties of the material and is the fraction if the primary beam removed per unit distance.
- The photoelectric effect predominates over the compton interaction in high atomic number materials, e.g. In bone below 50 keV, and in soft tissue below 30 keV.
- In soft tissue the characteristic radiation produced is very low energy that it is absorbed locally.
- The probability of the Compton effect, decreases only slightly with increasing energy over the photon energies used in diagnostic radiology.
- The Compton effect predominates in CT because of the higher energy photons used compared to general X-ray.
- Examples- Regarding X-ray attenuation in materials:
    - The half value thickness of a material is inversely proportional to its linear attenuation coefficient- TRUE
    - The photoelectric effect predominates in soft tissue above 30keV- FALSE
    - Photoelectric interactions in soft tissue, give rise to characteristic radiation of such low energy, that it can be considered locally absorbed at the site of interaction- TRUE
    - The Compton linear attenuation coefficient reduces with increasing photon energy- TRUE
    - The high contrast seen in CT, is not due to the photoelectric effect- FALSE

Imaging in mammography

- In mammography, single coated films are used
- The focal spot is smaller, 0.3mm or less
- The x-ray tube has a molybdenum target and is used at 28kVp with a molybdenum filter. Other combinations, like rhodium are used for thicker breasts, along with a higher kV technique.
- The heel effect is helpful when the chest wall is placed nearer the cathode, where the beam is more intense.
- Examples- In an imaging system for mammography:
    - An x-ray tube with a rhodium target and filter can be used- TRUE
    - A focal spot size of greater than 0.5mm is advised to allow greater tube currents and reduce exposure times- FALSE
    - A single sided emulsion is never used- FALSE
    - Tube potential in the range 17-19 keV is normally selected- FALSE
    - The heel effect must be minimised in mammography tube design- FALSE

Quality assurance of diagnostic X-ray equipment

- Output is measured with an electronic kV meter. Output is proportional to kV2.
- Leeds test objects are used to test image quality and require the subjective assessment of images of various test objects.
- Focal spot size can be measured with a pinhole camera or star test object.
- For standard radiographic installations one would normally except the measured value to be within +/- 5kV or 5% of the normal value. It is usually recommended that errors or 10kV or more be corrected before further use. Mammography equipment is subject to tighter controls.
- Examples – Regarding quality assurance of diagnostic x-ray equipment:
  - kVp accuracy should be checked at least annually- TRUE
  - Leeds test objects may be used to measure tube output- FALSE
  - Poor film screen contact produces blackening of the film- TRUE
  - Focal spot size may be measured using a star test object- TRUE
  - kVP accuracy of +/- 10 kV is acceptable- FALSE

Dose to patients

- Decreasing the kVp results in an increase in mAs to maintain a constant receptor dose, which gives rise to film blackening, resulting in an increase in patient dose.
- An aluminium filter attenuates the lower energy x-rays more in proportion to the high energy x-rays, reducing skin dose to the patient without affecting the image.
- A compression band reduces the thickness of tissue irradiated.
- Grids reduce scatter reaching the film; they result in an increase in dose to the patient as a greater mAs are required for the same exposure. Low ratio grids are less selective. So they will allow more scatter to reach the film, but will allow exposure factors to be reduced.
- Examples- The dose to a patient may be reduced when using a film screen system by:
  - Selecting a lower receptor dose on the automatic exposure control for a given tube potential- TRUE
  - Reducing beam filtration- FALSE
  - Removing any compression band present- FALSE
  - Decreasing the object to film distance- FALSE
  - Using a low ratio grid- FALSE

Stochastic Effects

- Stochastic effects are assumed to be a linear function of dose with no threshold dose.
- The probability of the effect occurring (rather than its severity) increases with dose.
- Stochastic effects induce cancer.
- Examples- A stochastic radiation effect is one in which:
    - There is a threshold dose level below which no effects occur- FALSE
    - The severity of the effect varies with dose- FALSE
    - The probability of the effect occurring varies with dose- TRUE
    - Cataract of the lens is an example- FALSE
    - Leukaemia is an example- TRUE

Dose

- Absorbed dose- measured in Gy- is the amount of energy imparted per unit mass to a medium by the incident radiation.
- Equivalent dose- measured in Sv- is the product of the absorbed dose and a radiation weighting factor (w_R). This is because the same organ dose will not produce the same biological effects of the radiation type is different.
- Radiation weighting factor = 1 (x-rays, γ-rays & electrons) , 5 (protons), 20 (alpha particle) &5-20 (neutrons).
- Equivalent dose is combined with the tissue weighting factor to calculate effective dose E, also in Sv. Which is then weighted again (according to tissue type) with factor W_T.
- Examples- Equivalent dose is a quantity that:
    - Is averaged over all tissues of the body- FALSE
    - Uses a radiation weighting factor to account for differences in biological effectiveness of different types of radiation- TRUE
    - Is used to set occupational dose organ limits- TRUE
    - Has the same weighting factor for X-rays and γ-rays- TRUE
    - Is measured in Sieverts (Sv)- TRUE

Air materials in quantity of radiation

- Air has an effective atomic number (7.6), close to that of soft tissue (7.4). In an unsealed air chamber the pressure and temperature will affect the number of gas molecules in the chamber and can affect the reading.
- In diagnostic radiology dosimetry an error of a few percent may be acceptable in the context of other errors.
- In radiotherapy a correction will have to be taken into account.
- Free air chambers will have to be taken into account and are housed in national standards laboratories (being 800 times the size of thimble chamber).
- IRR (2017) does not specify how dose is measured, but the quantities measured have to conform to international standards of measurement and quantities.
- Examples- Ionisation in air or air-equivalent material is commonly used to measure the quantity of radiation because:
    - Air has a similar atomic number to muscle tissue- TRUE
    - The effects of changes in temperature and pressure are small, they can normally be ignored in diagnostic radiology dosimetry- TRUE
    - Ionisation currents are large enough to be measured with a simple ampmeter- FALSE
    - Free air chambers can be made very compact and simple to use- FALSE
    - The IRR (2017) states that it must be used- FALSE

Radiation safety in nuc med

- Dose monitoring badges are ineffective in detecting surface contamination for which a contamination monitor is required.
- Scintillation crystal monitors are ideal for measuring personal contamination from electron capture or γ emitting nuclides
- Mouth pipetting is not permitted under any circumstances.
- Following a spill decontamination should be carried out. This involves the use of water, mild detergents, and swabs which are then sealed in plastic bags and disposed of as radioactive waste in marked bins under an agreed waste disposal procedure.
- Lead aprons are ineffective against the high-energy γ-rays of Tc and generally local shielding is much more effective at reducing dose rates.
- Examples- Regarding radiation safety in nuclear medicine, when administering doses to patients:
    - Portable scintillation monitor is not suitable for the measurement of personal contamination from electron capture nuclides- FALSE
    - When drawing up injections finger doses may be reduced by keeping the active bolus in a syringe away from the fingers- TRUE
    - Radioactive solutions of low specific activity may be pipetted by mouth- FALSE
    - Because of the short half-life of all nuclides, spills may be left to decay safely- FALSE
    - 0.25mm lead aprons will provide effective protection against 140 keV photons- FALSE

Film-Screen Combinations

- Film speed is the reciprocal of the air kerma needed to produce D = 1, which is the average density of a properly exposed radiograph.
- It is affected by: Photon energy of the x-rays (typically greatest at 30-40 keV), presence or thickness of the screen, atomic number of the screen material & film grains (narrower, aligned grains are more likely to stop most of the x-rays compared with rounded grains)
- Also affected by development effects: concentration of developer, developer temperature and development time.
- The shape of the characteristic curve is largely determined by the properties of the film because of the range of grain sizes affecting γ.
- The saturation density cannot normally be exceeded as it is fixed level dependent on the properties of the film. At very high doses reversal can happen however, with high kV techniques reducing subject contrast enabling the effective latitude of the images to be increased.
- A fast screen, using phosphor with a high X-ray to light conversion efficiency, requires a lower x-ray dose or exposure (fewer protons/mm2) and give a worse signal to noise ratio.
- Examples- The speed of a film/screen combination is affected by the:
    - Energy of the incident X-ray- TRUE
    - Thickness of the screen- TRUE
    - Shape of the film grains- TRUE
    - Atomic number of the screen material- TRUE
    - Developer temperature- TRUE
  - The following statements about film/screen combinations are true:
    - The shape of the characteristic curve is largely determined by the properties of the film- TRUE
    - Increasing the developer temperature increases the saturation density of the film- FALSE
    - Less than 10% of the film density is due to the direct effect of the x-rays on the film- TRUE
    - The use of high kV techniques increases the latitude- TRUE
    - Phosphors with a high x-ray to light conversion efficiency reduce noise- FALSE

Scintillation detector using NaI crystal

- Efficiency of the crystal is dependent on its thickness. It is hygroscopic so must be in a sealed in a container.
- The size of the pulse from the photomultiplier tube is proportional to the original γ-ray energy.
- Gamma rays can not be focused. Instead of a lens, a multihole collimator is used to delineate the image from the patient. The primary function of the collimator is therefore not to reduce scatter.
- Examples- In a scintillation detector using a NaI crystal:
    - The efficiency depends on the thickness of the crystal- TRUE
    - The output pulse from the photomultiplier tube is dependent on the energy of the γ-ray detected- TRUE
    - High energy B-particles are detected- FALSE
    - The NaI crystal is hygroscopic – TRUE
    - A collimator is used to reduce scatter- FALSE

Radioactivity in a generator

- The activity of 1Bq = 1 disintegration per second.
- In transient equilibrium the daughter decays as quickly as it is formed- such that the daughter and parent decay together with the half-life of the parent .
- If the half-life of the daughter is shorter than the parent, then in equilibrium the activity of the daughter present is independent of its own half-life. The amount of daughter present decays exponentially with the activity of the parent.
- Activity is related to the time between elutions as it takes time for the amount of daughter to regenerate after each elution.
- When the daughter is in transient equilibrium with the parent nuclide, the daughter is decaying as fast as it is being formed. The daughter and parent decay together (i.e. Same activity) with the half-life of the parent.
- At the same time more daughter is being formed from the parent. After 24h the activity has grown again to a new maximum (equilibrium) for a Mo99/Tc99m generator. By definition if parent and daughter are in equilibrium then the time since the last elution is irrelevant, however the amount of daughter present will depend on the time since the last elution.
- Examples- Concerning radioactivity in a generator:
    - Activity of 1 MBq = 1 disintegration per second- FALSE
    - The daughter always decays with the same activity as the parent when in equilibrium- TRUE
    - The activity is independent of the half-life of the daughter- TRUE
    - The daughter decays exponentially when at equilibrium- TRUE
    - The activity is not related to the time between elutions- FALSE
  - In a parent-daughter radionuclide generator, the amount of activity of the daughter at equilibrium:
    - Is constant- FALSE
    - Is dependent on the volume of the volume of the element- FALSE
    - Is much less than the activity of the parent- FALSE
    - Is independent of the half-life of the daughter – TRUE
    - Is independent of the time since the column was last eluted- TRUE

Modulation Transfer Function

- MTF measures information in the image/information in the object.
- Every imaging system suffers from loss of information and so has a MTF.
- It is affected by any aspect of imaging that can result in a blurred image.
- It is used to: compare imaging systems, assess deterioration in performance of a system & measure the MTF of each separate component of an imaging system.
- Example- The modulation transfer function:
    - Expresses the ration of the recorded information to the available information in the X-ray beam- TRUE
    - Reflects the information lost when x-rays are recorded- TRUE
    - Of a system only depends on its resolution- FALSE
    - May be derived from Fourier analysis- TRUE
    - Does not allow comparison of alternative imaging systems- FALSE

CT

- The brightness or grey scale value of each pixel represents the average linear attenuation coefficient of the contents of the corresponding voxel.
- Nearly all CT is operated at a kVp of 140, at these high energies Compton interactions predominate in the patient.
- A “bow-tie” filter is used providing a filtration equivalent to 0.5mm of copper.
- Narrowing of the window width increases contrast as it allows small differences of CT number to be selected from the full range and displayed over the whole grey scale.
- Examples- In computed tomography :
    - The pixel value represents the linear attenuation coefficient in a voxel- TRUE
    - Compton interactions predominate in the patient- TRUE
    - 5mm copper filtration is required- FALSE
    - Fat has a typical value of -100 Hounsfield units- TRUE
    - Narrowing of the window width decreases contrast in the processed image- FALSE

Beta Particles

- In B decay an electron is ejected from the nucleus with high energy and is called a B- particle.
- There is no change in mass number, but the atomic number increases by one.
- As a B particle passes through tissue it causes ionisations and excitations of atoms in the materials along its track until it has lost all its energy.
- The total range involved in tissue interactions is a few millimeters at most, but in air is a few meters. Phosphorus 32 can travel up to 6m in air.
- Examples- Beta Particles:
    - Are associated with nuclear decay- TRUE
    - Are not associated with a change in mass number during radioactive decay- TRUE
    - Increase atomic number by one during radioactive decay-TRUE
    - Contribute to patient absorbed dose- TRUE
    - May travel for a few metres in air if energetic- TRUE

X-ray spectra

- A molybdenum filter transmits most of the characteristic radiation but removes most of the continuous spectrum of a molybdenum target.
- A lot of low energy photons are produced at the target via bremsstrahlung, but they are almost all filtered by the tube housing, glass wall and added filtration.
- The focusing cup acts to prevent the electron stream from spreading and striking the target over a large area which would otherwise lead to blurring.
- Examples- The following statements are true concerning X-ray spectra:
    - Characteristic X-rays contribute more to a mammography tube target spectrum than they do with a general radiography tube- TRUE
    - Very few x-rays less than 10KeV are created at the target- FALSE
    - X-ray spectra used in CT usually have a higher effective energy than those used in fluoroscopy- TRUE
    - The shape of the bremsstrahlung spectrum is a strong function of the design of the focusing cup at the filament- FALSE
    - The X-ray spectrum can be measured using a scintillation detector- TRUE

The Diagnostic X-ray tube

- If an x-ray tube is operated below the K absorption edge of the target anode material no characteristic radiation is produced (i.e. Ka or Kb lines cannot be seen in the x-ray spectrum), however the spectrum still shows the continuous bremsstrahlung shape always evident with an x-ray spectrum and is therefore not monoenergetic.
- Even using a K-edge target and filter, other portions of the x-ray spectrum are still evident, although reduced. Some mobile image intensifier X-ray systems utilise rotating anode x-ray tubes.
- The maximum current density falling on the target anode puts limitations in the tube current and focal spot size → hence the number of x-ray photons per mm2 will be constant for fine and broad focus.
- A large focus is used for thicker parts of the body that require a greater intensity of X-rays (and hence a higher tube current) order to keep exposure times accectably short.
- Smaller focal spots give better resolution, but at the expense of lower tube current and longer exposure times.
- X-ray tube life depends on its workload history and how it has been used, but is not accurately predictable. Several years is possible.
- Mobiles do not require high speed tubes because of tube loading.
- Examples- The diagnostic X-ray tube:
    - Never produces a monoenergetic x-ray spectrum is operated with a k-edge absorption filter the same as the target material- TRUE
    - A fixed rather than rotating anode system is used on all mobile image intensifier systems- FALSE
    - On broad focus emits more photons per mm2 compared to fine focus- FALSE
    - Tube replacement may not be required for some years- TRUE
    - Higher anode spin speeds are required on mobiles because of higher tube loading- FALSE

Effect of grid

- The amount of scatter reaching the film may be reduced, and contrast increased, by putting a grid between the patient and the film.
- Using a grid requires an increase in the mAs, increasing the dose to the patient from primary and scattered radiation.
- Examples- The effect of a grid is to:
    - Increase the dose resulting from scattered radiation to the patient- TRUE
    - Reduce the radiographic contrast- FALSE
    - Decrease the necessary exposure- FALSE
    - Decrease the penetration of the radiation- FALSE
    - Increase the scattered radiation reaching the film- FALSE

Filtration

- Increasing filtration:
  - Increases the penetrating power (HVL) of the x-ray beam.
  - Increases the minimum and effective photon energies but does not affect the maximum photon energy.
  - Reduces the area under the energy fluence spectrum and the total output of X-rays.
  - Increases the exit dose/entry dose ratio or film dose/entrance surface dose ratio.
- Examples- Assuming image receptor dose remains constant, additional beam filtration of an X-ray beam:
    - Decreases the mean photon energy of the beam- FALSE
    - Decreases the half value thickness- FALSE
    - Increases the skin entrance surface dose (ESD)- FALSE
    - Decreases the dose to the superficial tissues- TURE
    - Decreases the radiographic contrast in the image receptor- TRUE

Scatter

- Film-screen combinations do not affect scatter around the patient. Measures to reduce the amount of scatter produced by the patient include:
  - Reducing the field size, compression of the patient and lowering the kV.
- Increased filtration leads to beam hardening, which increases average photon energy in the spectrum. This tends to increase the proportion of Compton interactions taking place out of the total number of interactions.
- Scattered photons may have high enough energy to escape the body thus giving rise to a scatter dose in the vicinity of the patient.
- By increasing filtration, although the % of compton interactions increases, the total number of all interactions decreases.
- Increasing the focus skin distance has the effect of increasing the area irradiated on the patient but does not change the total number of photons reaching the patient → the scatter will therefore remain the same.
- Increasing the object to film distance (i.e. An air gap) reduces scatter to the film leaving the scatter from the patient unchanged.
- At diagnostic X-ray exposures measured scatter doses are greater on the entrance side, i.e. Backward scatter, due to absorption of the forward scattered beam in the patient.
- Examples- For a given set of exposure factors the scatter around a patient is:
    - Increased by calcium tunstate screens as opposed to rare earth screens- FALSE
    - Increased by increasing the radiation beam size- TRUE
    - Increased by increasing the filtration- FALSE
    - Decreased by increasing the focus to film distance- FALSE
    - Less backwards than forwards- FALSE

Effective focal spot size

- Effective focal spot size is determined by:
  - The target angle
  - The actual focal spot size, which in turn is determined by: The size of the filament and the presence of a focusing hood.
- Examples: The effective focal spot size of a rotating anode tube is influenced by:
  - The angle of slope of the anode- TRUE
  - The size of the filament- TRUE
  - The speed of the anode rotation- FALSE
  - The diameter of the anode disc- FALSE
  - The anode film distance- FALSE

Air Gap

- In the air gap technique the film is moved 30cm away from the patient so that much of the wide angled scatter misses the film.
- The technique requires an increase in the kV or mAs. A wide latitude low γ film-screen combination is required for chest radiography enabling the range of “exposure” between bones, mediastinum and lung in the thorax to be captured on the film.
- Often a high kV is used to reduce subject contrast therefore reducing the required latitude of the film/screen combination.
- Examples- The following statements are true when using the air gap technique in PA chest radiography:
    - Wide angled scattered radiation misses the film- TRUE
    - Slow intensifying screens are required- FALSE
    - The focus to film distance must be increased- FALSE
    - Radiographic kV must be lower than with conventional chest radiography- FALSE
    - The air gap must be atleast 30cm- TRUE

Mammography

- For magnification of suspicious lesions, 0.1mm focal spots are used.
- Rhodium or even palladium can be used as beam filter materials with higher kVs for thicker breasts.
- As well as reducing dose, compression immobilises the breast, reduces object film distance (reducing film blurring) and equalises tissue thickness.
- Here the anode heel effect is useful and the thicker part of the breast can be positioned towards the cathode where the exit beam is more intense.
- A very fine moving grid is used to improve contrast.
- Examples- In mammography:
    - A focal spot of 0.5mm should be used for magnification- FALSE
    - Palladium is used as a target material- FALSE
    - The use of compression reduces patient dose- TRUE
    - The anode heel effect is useful- TRUE
    - A stationary grid is used in preference to a moving grid- FALSE

Film-screen dose

- The film screen is proportional to kV^4 x mAs. $80^4/60^4 = 3.16$. Therefore to achieve the same image receptor dose (related to film blackening), the mAs need to be cut to 32% of its previous value.
- A higher kV increases the penetration of the beam (fewer photoelectric interactions) and reduces patient dose. A lower KV increases film contrast.
- Examples- Increasing the tube potential from 60 to 80 would be expected to have the following effects:
  - Require the use of a $CaWO_4$ screen- FALSE
  - Increase the relative number of photoelectric interactions in the patient- FALSE
  - Reduce the film contrast- TRUE
  - Increase the radiation dose to the patient, for the same image receptor dose- FALSE
  - Require the mAs to be reduced to approximately 32% of its previous value to achieve the same image receptor dose- TRUE

Entrance surface dose

- The intensity of an X-ray beam is:
  - Proportional to Kv^2
  - Greater for a constant potential than a pulsating potential.
  - Proportional to the mA
  - Decreased as the filtration is increased
  - Inversely proportional to the square of the distance from the target
  - Greater for higher atomic number targets than lower atomic number targets
  - It falls inversely as the square of the distance
- Examples- The entrance surface dose rate measured at the beam entry point of the patient's skin:
  - Decreases with field size- FALSE
  - Decreases with the current flowing between cathode and anode- FALSE
  - Is proportional to the atomic number (Z) of the target- TRUE
  - Varies as the square of the focal spot to patient distance- FALSE
  - Varies with the amount of filtration used in the beam- TRUE

Grid Ratio

- Grid ratio is the height of the lead strip divided by the distance between them.
- Grid factor is the exposure necessary with a grid divided by the exposure necessary without it.
- Primary transmission is the measure of the tendency of the grid to reduce primary radiation and is of the order of 70%.
- Examples- The term grid ratio is:
  - The height of the lead slots compared to the area of the grid- FALSE
  - The exposure time with the grid divided by the exposure time without it- FALSE
  - The attenuation in the lead compared to the attenuation in the interspace material- FALSE
  - A measure of the ability of the grid compared to the area of the grid- FALSE
  - Related to the thickness of the grid compared to the area of the grid- FALSE

Tld

- When x-ray or γ-rays are absorbed by thermoluminescent (TL) material, atomic electrons are raised to higher energy levels and stay in their excited state (electron trap) indefinitely.
- TL material can be made in a range of sizes allowing measurement of finger and eye doses.
- Precision of 1% is only achievable with electronic dosimeters.
- TLDs do require calibration.
- Processing of TLD can involve heating up to 300-400^{o}C.
- Examples- TLD is an important dosimeter method because:
  - Ionisation in thermoluminescent materials results in electrons being trapped- TRUE
  - Thermoluminescent material can be made in a range of sizes- TRUE
  - TLD has a precision better than 1%- FALSE
  - It does not require independent calibration- FALSE
  - It is unaffected by temperature over a very wide range- FALSE

Quantum Mottle

- The larger the number of X-ray photons absorbed the less quantum mottle. Only using a longer exposure time or exposing a film twice, increases the number of photons absorbed on a film.
- The use of screens increases quantum mottle because fewer photons are needed for the same film blackness.
- Examples- Quantum mottle can be reduced by:
  - Developing the film longer- FALSE
  - Using a longer X-ray exposure- TRUE
  - Using a thicker intensifying screen- FALSE
  - Raising the temperature of the developer- FALSE
  - By exposing the film twice- TRUE

Film-Fog

- Fog is the density of processed but unexposed film.
- Inherent fog is due to some of the silver bromide crystals having acquired latent images during manufacture, and the film base absorbing light when viewed.
- Additional fog may arise from:
  - Increasing film age
  - Incorrect storage (high temp and humidity)
  - Increasing developer temperature/time
  - Accidental exposure to X-rays
  - High film speed
- Examples- The following contribute to film-fog formation:
  - The construction of the cassette used- FALSE
  - The dye used in the base- TRUE
  - The support provided for the phosphor in the screen- FALSE
  - The binder used in the intensifying screens- FALSE
  - The duration of the developing process- TRUE

Film Processing

- Developing→ immersion in an alkaline solution of reducing agent to reduce silver ions to silver atoms. If the temp is too high, the reducing agent will start to react with non-ionised grains forming a background image, increasing fog.
- Washing
- Fixation by an acid solution of thiosulphate which removes unaffected silver ions. The fixer contains aluminium salts which harden the film and reduce the drying time.
- Washing→ The results of inadequate washing are that any retained thiosulphate turns brown/yellow.
- Drying
- Film speed, γ and fog are affected by:
  - Concentration of developer
  - Developer temperature
  - Development time
- Examples- During film processing:
  - The film γ may be affected- TRUE
  - The temperature is closely related to the optical density- TRUE
  - The processing time tends to be constant across all types of film- FALSE
  - The developer does not reduce silver bromide in the image- FALSE
  - The fixer does not harden the emulsion- FALSE

Image intensifier

- The image intensifier at the output phosphor has a spatial resolution of 4-5 lp/mm.
- Veiling glare, due to scattering of light reduces contrast and is worse with the larger sizes of intensifier.
- Magnification increases input to retain the same output brightness.
- Quantum mottle (noise) is particularly noticeable in fluoroscopy unlike in radiography.
- Dose rates on the input surface of the image intensifier are of the order of 0.5 $uGys^{-1}$ in fluoroscopy; the typical skin dose may be around 300 times greater.
- Examples- In a caesium iodide image intensifier system:
  - Limiting spatial resolution of 20 line pairs per mm at the output phosphor may be expected- FALSE
  - Contrast is dependent on the image intensifier input diameter- TRUE
  - The image intensifiers input dose rate reduces when selecting magnified fields- FALSE
  - The minimum visible detail size is smaller on plain film radiographs than in the fluoroscopic image- TRUE
  - The measured patient maximum ESD should not exceed 100 mGy/min- TRUE

Staff protection

- Protective clothing does not protect against the direct beam, only radiation attenuated or scattered by the patient.
- Aprons have a lead equivalent of 0.25 to 0.5mm.
- A 0.25mm thick lead apron transmits less than 10% of 90 degree scatter for a 100 kVp scattered beam.
- Examples- Regarding staff protection:
  - The heaviest tolerable lead apron should be worn- TRUE
  - Aprons have a lead equivalent of 1.25 to 1.5mm- FALSE
  - Lead aprons afford adequate protection from the primary beam- FALSE
  - Lead gloves afford adequate protection from the primary beam- FALSE
  - A standard lead apron will transmit less than 10% of the incident dose at 100 kV- TRUE

IRR (2017) (2)

- Under IRR (2017) an employee must become a classified if three-tenths of a dose limit are exceeded.
- In the case of the lens of the eye this is 30% of 20 mSv or 6 mSv
- Different employers are required to co-operate with dose monitoring under IRR (2017), but there is no absolute necessity to make shared workers classified.
- Examples- Under IRR (2017), an employee must become a classified worker if:
  - The dose to their eyes is likely to exceed 20 mSv annually- FALSE
  - They are likely to receive an annual effective dose greater than 6 mSv- TRUE
  - Four-tenths of a relevant dose limit is exceeded- FALSE
  - They work in different locations- FALSE
  - They become pregnant- FALSE

IRMER (2017)

- Referrers are registered medical or dental practitioners, or other health professionals who are entitled to refer patients for medical exposure to a practitioner.
- Entitlement is a local decision.
- Employers need procedures for identifying all referrers. The practitioner and operator needs to be adequately trained; not the referrer.
- Examples- Under IRMER (2017), the following are true regarding “referrers”:
  - Only doctors and dentists are permitted to request an X-ray- FALSE
  - They can request anything from “making best use of a department of clinical radiology”- FALSE
  - Their identities must be kept by the employer- TRUE
  - They must provide sufficient relevant clinical information to allow justification of the exposure- TRUE
  - They must be adequately trained- FALSE

Radiation dose in radionuclide imaging

- The absorbed dose delivered to an organ increases in proportion to:
  - The activity administered to the patient
  - The effective half-life in the organ
  - The energy of β and γ radiation emitted in each disintegration
- The maximum usual dose of a thallium-201 myocardial scan is approximately 18 mSv.
- The dose delivered by a radionuclide examination is unaffected by the number of images taken.
- Examples- In radionuclide imaging the radiation dose to the patient is:
  - Dependent on the energy of the γ photon emissions- TRUE
  - Inversely proportional to the administered radioactivity- FALSE
  - Dependent on the biological half-life of the radiopharmaceutical- TRUE
  - Usually greater than 20 mSv for a patient undergoing a Thallium-201 myocardial scan- FALSE
  - Dependent on the image acquisition time- FALSE

CT Dose

- The dose increases with the number of slices. By increasing the spacing, fewer slices will be imaged.
- Dose is proportional to mA.
- Increasing the number of detectors has no effect on dose.
- In spiral scanning the dose depends very much on the scan protocol and it does not always follow that doses will be lower. However, in long acquisitions tube loading may be a limitation and a lower mA may be used resulting in a lower patient dose.
- As each slice needs to be reconstructed by all the ray paths available through the volume, all the detectors need to be used even with a smaller selected field of view (FOV). Hence selecting a smaller FOV will not affect the dose.
- Examples- The effective dose in CT of the abdomen will be reduced by:
  - Increasing the spacing between slices- TRUE
  - Increasing the mA, other factors remaining constant- FALSE
  - Increasing the number of detectors- FALSE
  - Using spiral scanning rather than selective scanning- FALSE
  - Decreasing the field of view- FALSE